Historic, archived document

Do not assume content reflects current scientific knowledge, policies, or practices.

SHOUT
SHARE
IT

UNITED STATES DEPARTMENT OF AGRICULTURE

DEPARTMENT BULLETIN No. 1304

Washington, D. C. ▼ March 17, 1925

CROP ROTATION AND CULTURAL METHODS AT THE AKRON (COLORADO) FIELD STATION

In the 15-Year Period from 1909 to 1923, Inclusive

By J. F. BRANDON, *Associate Agronomist, Office of Dry-Land Agriculture Investigations, Bureau of Plant Industry*

CONTENTS

	Page		Page
History of the investigations	1	Results with barley	16
Soil	2	Results with corn	17
Climatic factors	2	Results with other crops	19
Scope of the experiments	7	Fallow	22
Average yields	9	Green manures	23
Results with winter wheat	10	Crops on prairie sod	24
Results with spring wheat	12	Soil blowing	24
Results with oats	14	Summary and recommendations	26

HISTORY OF THE INVESTIGATIONS

The Akron Field Station, located 4 miles east of Akron, Colo., is operated by the Office of Dry-Land Agriculture Investigations of the Bureau of Plant Industry, United States Department of Agriculture. The station was established in 1907. The preparation of the land was uniform for the first crop, which was grown in 1908. The results of rotation and tillage practices consequently begin with 1909. This bulletin reports the experimental data and results on crop rotations and cultural methods at the station for the 15 years from 1909 to 1923, inclusive.

The Akron station is one of 24 in the Great Plains region at which coordinated experiments in crop rotations and cultural methods have been conducted by the Office of Dry-Land Agriculture Investigations,[1] either independently or in cooperation with other offices of

[1] The Office of Dry-Land Agriculture Investigations was organized in 1905, with E. C. Chilcott as agriculturist in charge. He outlined and instituted these investigations and still has general supervision over them. This bulletin has been prepared under his direction. The work at Akron was established under the direct supervision of J. E. Payne, superintendent, who was succeeded by O. J. Grace in 1910; he, in turn, was succeeded by the writer in 1920. Other members or former members of the scientific staff of the Office of Dry-Land Agriculture Investigations having to do with procuring the data presented in this bulletin are W. M. Osborn, A. E. Seamans, L. N. Jensen, W. E. Lyness, A. Osenbrug, and Clarence Harris. The climatic data were obtained through cooperation with the Biophysical Laboratory of the Bureau of Plant Industry.

13451°—25†——1

the United States Department of Agriculture or the State experiment stations. Results of experiments at the other stations throughout the Great Plains have been of great value in interpreting the data of the Akron station, which is representative of a very large area of the west-central Great Plains.

SOIL

The soil on which these experiments have been conducted is a light to dark brown sandy loam with a clay to clay-loam subsoil interspersed with sand pockets. This soil is typical of the so-called hard land of this region. The so-called soft land has a sandy surface with a sandy subsoil. In its native state the hard land is characterized by a short-grass vegetation composed chiefly of two species, grama grass (*Bouteloua gracilis*) and buffalo grass (*Bulbilis dactyloides*); whereas the soft land is characterized by a growth of wire-grass (*Aristida longiseta*), bunch grasses (chiefly characterized by *Andropogon scoparius*), and sand sage (*Artemisia filifolia*).[2]

TABLE 1.—*Monthly, seasonal, and annual precipitation at the Akron Field Station for the 16-year period from 1908 to 1923, inclusive*

[Data in inches. T=trace]

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Seasonal, Apr.–Sept., inclusive	Annual
1908	0	0.34	T	1.70	3.30	2.37	2.42	1.47	0.05	3.20	2.00	T	11.31	16.85
1909	T	1.38	3.06	.40	1.87	3.32	4.61	3.77	2.16	.86	.48	0.55	16.13	22.46
1910	.05	.16	.26	3.96	2.06	1.38	1.47	3.72	3.81	.05	.12	.32	16.40	17.36
1911	.60	.44	.06	2.63	1.15	1.48	1.34	1.30	2.40	1.47	.28	1.36	10.30	14.51
1912	.28	1.43	.78	2.49	2.86	3.39	3.58	1.58	1.88	1.99	.18	.29	15.78	20.73
1913	.22	.40	1.57	2.19	1.44	1.35	1.85	1.14	2.08	.34	.70	3.27	10.05	16.55
1914	.03	.32	.20	4.01	1.46	3.54	1.66	1.05	.23	2.08	.10	.90	11.95	15.58
1915	1.10	1.68	1.50	5.19	4.13	3.75	1.10	3.51	1.76	.48	.15	.65	19.44	25.00
1916	.50	T	.09	1.59	2.24	2.09	1.77	2.82	.26	1.02	.75	.61	10.77	13.74
1917	.28	.63	.72	.96	7.79	.56	1.52	1.78	2.19	.57	T	.50	14.80	17.50
1918	.70	.80	.60	1.20	1.76	.96	3.10	7.36	2.43	1.07	.75	1.55	16.81	22.28
1919	.07	.50	.65	1.96	1.59	2.27	1.79	.44	2.62	1.64	1.29	.70	10.67	15.52
1920	T	.02	.90	3.28	2.90	3.97	4.72	1.45	1.80	.44	.47	.90	18.12	20.85
1921	1.22	T	1.25	2.77	.47	1.32	2.88	.92	.79	.97	.20	.65	9.15	13.44
1922	.65	.25	.15	3.96	3.63	1.43	3.24	1.24	.06	.05	1.90	.10	13.56	16.66
1923	T	.18	.95	1.65	4.94	2.17	3.62	.75	.82	1.91	.47	.70	13.95	18.16
Average	.36	.53	.80	2.50	2.72	2.21	2.54	2.14	1.58	1.13	.62	.82	[1] 13.69	17.95

[1] Sum of monthly averages.

CLIMATIC FACTORS

PRECIPITATION

The monthly precipitation for the 16-year period from 1908 to 1923, inclusive, at the Akron Field Station is given in Table 1. The average annual precipitation for this period was 17.95 inches. This average was exceeded by the yearly precipitation in but 6 of the 16 years. It therefore appears that the average annual precipitation is somewhat higher than the most probable precipitation. The most probable quantity would seem to be about 17 inches, since the yearly

[2] Shantz, H. L. Natural vegetation as an indicator of the capabilities of land for crop production in the Great Plains area. U. S. Dept. Agr., Bur. Plant Indus. Bul. 201, 100 p., illus. 1911.

precipitation has exceeded this eight times and has been below it eight times in the 16 years that records have been kept. The heaviest precipitation of any one year was 25 inches, in 1915. The lowest precipitation recorded for any one year was 13.44 inches, in 1921.

A general summing up of the cropping results shows conclusively that the greatest single factor in crop production is the amount of annual precipitation. The factor of greatest secondary importance appears to be the distribution of the precipitation, as the records available show that when the quantity approaches a critical point its distribution becomes the more important. Table 2 illustrates this point.

TABLE 2.—*Annual precipitation and average yields of the principal crops at the Akron Field Station in 1912, 1913, 1920, and 1921*

Year	Precipitation	Acre yields of the several crops					
		Winter wheat	Spring wheat	Oats	Barley	Corn	
						Grain	Total
	Inches	*Bushels*	*Bushels*	*Bushels*	*Bushels*	*Bushels*	*Pounds* [1]
1912	20.73	33.8	19.7	42.3	30.8	30.9	4,689
1913	16.55	7.4	3.9	6.6	6.3	3.9	1,611
1920	20.85	14.2	18.7	44.2	32.1	35.6	4,711
1921	13.44	12.3	2.1	13.1	14.1	6.3	1,190

[1] Total yield of grain and stover.

The years 1912 (20.73 inches) and 1920 (20.85 inches) had almost the same precipitation and produced very nearly the same acre yields of spring wheat, oats, barley, and corn. Winter wheat was an exception; it yielded much more heavily in 1912 than in 1920. In the years following these two a precipitation of 13.44 inches in 1921 produced decidedly better yields of most crops than a precipitation of 16.55 inches in 1913.

Table 3 furnishes data dealing with the seasonal precipitation and crop yields. The seasonal precipitation as referred to in this bulletin is the precipitation that occurs during the six-month period from April to September, inclusive.

TABLE 3.—*Seasonal precipitation and average yields of the principal crops at the Akron Field Station in 1911, 1916, and 1919*

Year	Precipitation	Acre yields of the several crops					
		Winter wheat	Spring wheat	Oats	Barley	Corn	
						Grain	Total
	Inches	*Bushels*	*Bushels*	*Bushels*	*Bushels*	*Bushels*	*Pounds* [1]
1911	10.30	4.1	3.7	4.0	6.1	3.2	1,367
1916	10.77	13.7	7.1	11.3	11.0	1.1	930
1919	10.67	15.0	6.3	16.9	18.3	4.5	1,620

[1] Total weight of grain and stover.

Three seasons having almost identical precipitations produced widely varying yields of the same crops, indicating a wide variation in the effectiveness of a given amount of precipitation. The effectiveness of the precipitation is dependent on how it is distributed over the growing season and by the extent to which it is supplemented by water in the soil at the beginning of the season.

The average seasonal precipitation from April 1 to September 30, inclusive, was 13.69 inches for the 16-year period under consideration. The seasonal precipitation was greater than this eight times and less eight times. The seasonal precipitation is 76 per cent, or about three-fourths, of the annual precipitation. The percentage of the seasonal of the total precipitation for each year varied from 61 per cent in 1913 to 94 per cent in 1910. Four times the percentage was below 70, eight times it was between 70 and 80, and four times it was

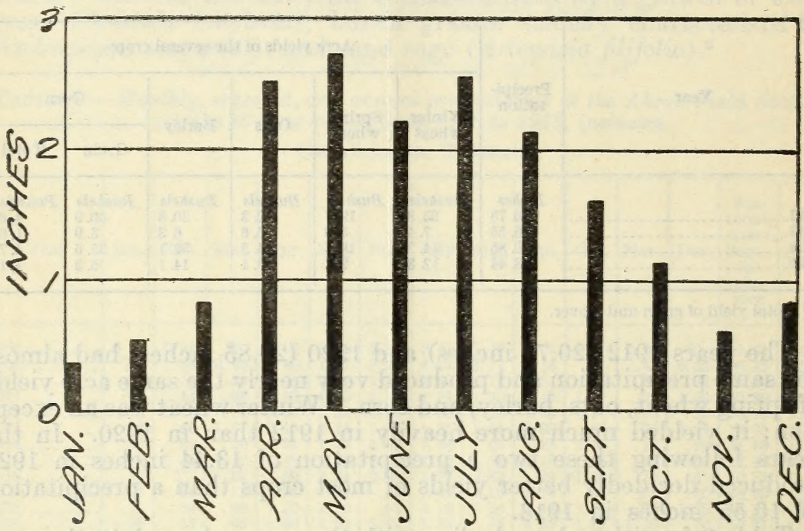

FIG. 1.—Average monthly precipitation at the Akron Field Station for the 16 years from 1908 to 1923, inclusive

above 80. The highest seasonal precipitation recorded was 19.44 inches, in 1915, and the lowest 9.15 inches, in 1921.

The average precipitation for the other six months of the year was 4.26 inches. The highest precipitation in any one six-month period from October to March, inclusive, was 9.64 inches, in 1908–09, and the lowest 1.59 inches, in 1910–11. The winter precipitation was less than 4 inches six times and greater than 4 inches nine times, but it exceeded 5 inches only three times. As a general rule, much of the winter precipitation is lost so far as crop production is concerned, as it usually occurs as snow accompanied by wind, which drives it off the open fields and piles it up in drifts. The more that farm practices or methods contribute to catching and conserving this winter precipitation falling as snow, the greater the advantage to the following crop yield.

The average monthly precipitation is shown in Figure 1.

WIND VELOCITY

The wind movement is recorded by a Robinson cup anemometer exposed at a height of 2 feet above the ground. The greatest average hourly wind velocity, 8.8 miles per hour, was in April. From this point the average hourly wind velocity rapidly drops off to the lowest point in the year, 5.4 miles per hour, in August. From this point the velocity very gradually builds up to 6.7 miles per hour, in January and February, from which point it rises rapidly to the peak in April. The average monthly wind velocity for the 12 years from 1912 to 1923, inclusive, is shown in Figure 2.

As a rule the heavy winds, such as cause damage to the crops, spring up during the daylight hours and settle down to comparative quiet with the close of the day. Exceptions are noted when high

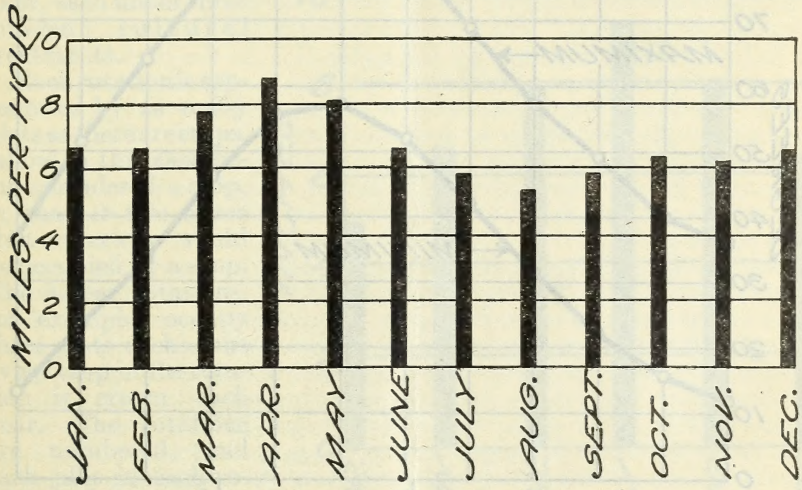

FIG. 2.—Average monthly wind velocity at the Akron Field Station for the 12 years from 1912 to 1923, inclusive

velocity persists for 24-hour periods or longer. Another general rule is that the high winds that do the most damage blow during the early spring months, when the highest average velocities occur. The greatest danger of soil blowing is during the months of January, February, and March. Again there are exceptions, one particular case being cited as June 18, 1923, when a southeast wind of sufficient velocity to cause soil movement and very serious damage to growing small-grain crops occurred.

TEMPERATURE

The climatic factors of this region are all influenced more or less by the altitude and the proximity to the mountains, but none perhaps more noticeably than the temperature. With an altitude of approximately 4,560 feet and the overshadowing influence of the Rocky Mountains, the frost-free period is considerably shorter than in lower altitudes to the east. The average frost-free period is approximately 140 days, extending from May 12 to September 29. Frost has been recorded as late in the spring as June 2, this being in 1919,

when for four days, beginning with June 1, the minimum temperatures were 32°, 31°, 32°, and 32° F. Frost has been recorded as early as September 13, this being in 1914.

The highest mean monthly maximum temperature is 87.6° F., in July and the lowest is 36.3° F., in January. The highest mean monthly minimum temperature is 57.3° F., in July and the lowest is 11.8° F., in January. The mean monthly maximum and minimum temperatures for the 12 years from 1912 to 1923, inclusive, are shown graphically in Figure 3.

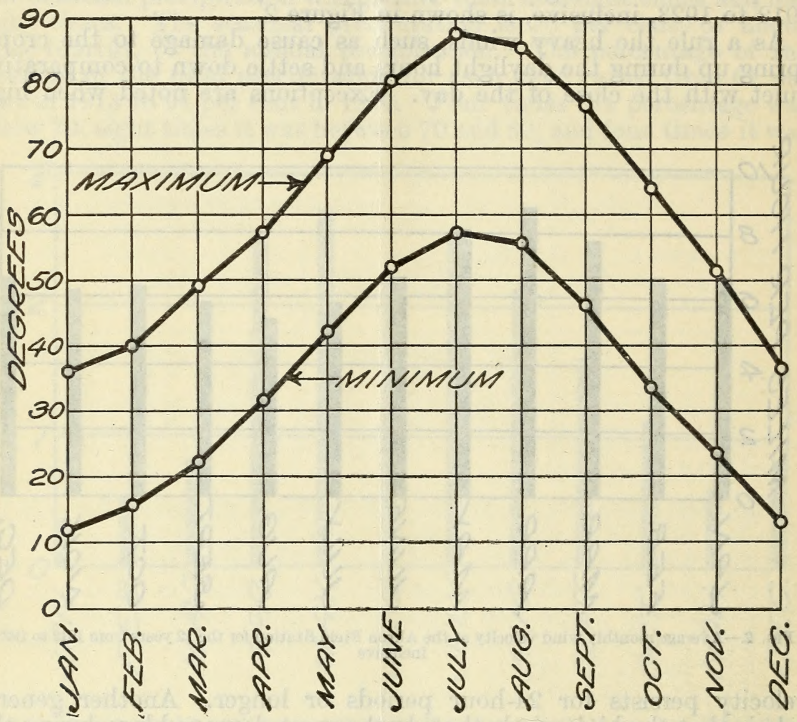

FIG. 3.—Mean maximum and minimum temperatures at the Akron Field Station for the 12 years from 1912 to 1923, inclusive

EVAPORATION

From April 1 to September 30, inclusive, daily measurements are made of the evaporation of water from an open tank 6 feet in diameter and 2 feet deep sunk to a depth of 20 inches in the ground. The water level is maintained at about the surface of the ground, 4 inches below the rim of the tank. The average monthly evaporation for the 16 years from 1908 to 1923, inclusive, is shown in Figure 4.

The average seasonal evaporation was 42.954 inches. This is approximately three times the precipitation during the same period. The highest average monthly evaporation is in July. Generally the evaporation rate is high in seasons when the precipitation is low, and low when the precipitation is greater and frequent.

SCOPE OF THE EXPERIMENTS

The rotation block as laid out in 1907 contains 144 tenth-acre plats. The plats are 2 rods wide by 8 rods long, separated on the sides by alleys 4 feet wide and on the ends by roadways 20 feet wide. The alleys and roadways are kept free from weeds.

Within this rotation block of 144 plats there are under experimentation ten 3-year rotations; sixteen 4-year rotations; two 6-year rotations; two groups of 7 plats each devoted to continuous cropping to corn and to spring wheat, each under six different cultural treatments; three groups of 6 plats each devoted to continuous cropping to winter wheat, oats, and barley, each under five different cultural treatments; and two groups of 3 plats each devoted to continuous cropping to milo and kafir, each under three different cultural treatments.

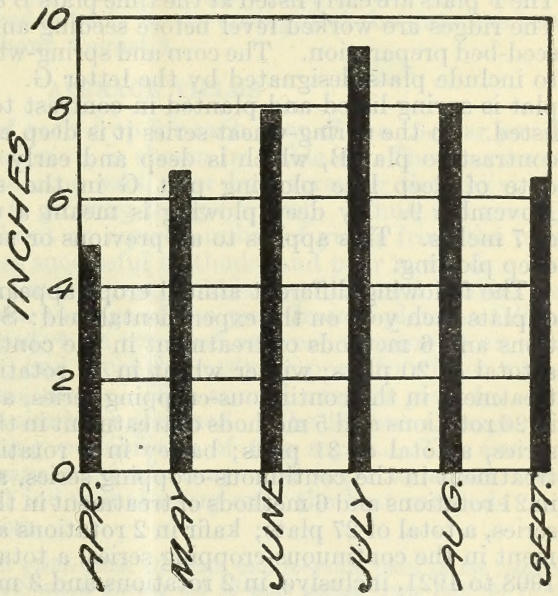

FIG. 4.—Average monthly evaporation at the Akron Field Station for the 16 years from 1908 to 1923, inclusive

Each rotation is represented by as many plats as there are crops, fallow in this case being considered a crop, in that it fills space that otherwise would be occupied by a crop. The 3-year rotations, for example, occupy three plats each; thus every crop in the rotation is grown each year. The rotations are numbered, and each plat in each rotation is lettered in the order A, B, and C.

The plat treatment throughout the continuous cropping series is coordinated. The A plats of these series are shallow-plowed immediately before seeding time and then given meager seed-bed preparation. The plowing is in the spring for spring-planted crops and in the fall for winter wheat. The B plats are deep plowed in the early fall and given good seed-bed preparation. The average date of plowing these plats is September 1. In the winter-wheat series plat B is early plowed and plat A is late plowed. Good seed-bed preparation is given in the spring just previous to seeding. Plats C and D are alternately cropped and fallowed; that is, one plat carries the crop one year while the other plat is being fallowed. The fallow plats in this pair were fall-plowed until 1918; since that time they have been spring-plowed. The average date of spring plowing these plats is June 3.

The practice is to plow at the time weed growth starts actively. After plowing, these plats are given the cultivation necessary to keep

them free from weeds throughout the season. The C plats in the milo and kafir series are fall-listed and are coordinate with the F plats of the other series, instead of the C plats with which their letters coincide. The listing, however, is later. The E plats are early deep fall-plowed at the same time as the B plats and in every other way are identical with those plats in their treatment, except that after intervals of two years they are subsoiled for two years in succession. The subsoiling operation consists of running a common single-nosed subsoiler in the bottom of each alternate plowed furrow. The subsoiler does not turn out any of the subsoil to be mixed and incorporated with the surface soil, but merely loosens it to a depth of 8 inches below the bottom of the furrow slice. In the years of subsoiling these plats are loosened to a depth of 15 or 16 inches below the surface. The F plats are early listed at the time plats B and E are early plowed. The ridges are worked level before seeding and the plats given good seed-bed preparation. The corn and spring-wheat series are extended to include plats designated by the letter G. In the corn series this plat is spring-listed and planted in contrast to plat F, which is fall-listed. In the spring-wheat series it is deep and late fall-plowed in contrast to plat B, which is deep and early plowed. The average date of deep late plowing plat G in the spring-wheat series is November 9. By deep plowing is meant a uniform plowing depth of 7 inches. This applies to all previous or subsequent allusions to deep plowing.

The following different annual crops appear in the stated number of plats each year on the experimental field: Spring wheat in 14 rotations and 6 methods of treatment in the continuous-cropping series, a total of 20 plats; winter wheat in 12 rotations and 5 methods of treatment in the continuous-cropping series, a total of 17 plats; oats in 26 rotations and 5 methods of treatment in the continuous-cropping series, a total of 31 plats; barley in 4 rotations and 5 methods of treatment in the continuous-cropping series, a total of 9 plats; corn in 21 rotations and 6 methods of treatment in the continuous-cropping series, a total of 27 plats; kafir in 2 rotations and 3 methods of treatment in the continuous-cropping series, a total of 5 plats; milo from 1908 to 1921, inclusive, in 2 rotations and 3 methods of treatment in the continuous-cropping series, a total of 5 plats; and sorgo in 1 rotation from 1908 to 1921, inclusive, and in 1922 and 1923 in 3 rotations and 3 methods of continuous cropping.

Since 1909, when cultural practices became established, these experiments have run continuously and now total 15 years. In that period the following aggregate number of plat-year records of the harvested annual crops have accumulated for study: Spring wheat, 300; winter wheat, 255; oats, 465; barley, 135; corn, 405; kafir, 75; milo, 71; and sorgo, 19. In addition to the annual crops, alfalfa and bromegrass each occupy 3 years of separate 6-year rotations. Besides the harvested crops already enumerated, winter rye in 6 rotations, peas in 6 rotations, and sweet clover in 2 rotations are plowed under for green manure. Fallow plats appear in 4 rotations, besides appearing once in each of the 5 series of continuous-cropping plats.

The varieties grown in these investigations were Beloturka (durum) spring wheat, Kharkof winter wheat, Kherson oats, Coast or California Feed barley, Swadley dent corn, Dawn or Blackhull kafir, Dwarf

Yellow milo, Dakota Amber sorgo, Giant winter rye, and Colorado field peas.

The rates per acre of seeding the various crops were—spring wheat, 4 pecks; winter wheat, 3 pecks; oats, 5 pecks; barley, 5 pecks; winter rye, 4 pecks; peas, 2 bushels; bromegrass, 15 pounds; alfalfa, 15 pounds; and sweet clover, 10 pounds. Sorgo, milo, and kafir were planted in 42-inch rows with the plants spaced 6 inches apart in the row, and corn in 42-inch rows with the plants spaced 24 inches apart.

The average dates of seeding the several crops were—winter wheat and winter rye, September 21; spring wheat, March 29; oats, April 3; barley, April 6; peas, April 12; corn, May 17; and the sorghums June 3. Sweet clover and bromegrass sown with spring wheat or oats as a nurse crop were sown at the same time as the crop. Alfalfa for many years was seeded early in the spring, but the date has been changed recently to about August 1.

AVERAGE YIELDS

The average yield of each crop for each year of the 15-year period from 1909 to 1923, inclusive, is shown in Table 4. These averages were obtained for each crop each year by averaging the individual yields from all the plats growing the given crop. Thus, the average yield is made up of about an equal number of yields from the most successful methods, less successful methods, and poor methods. The winter-wheat average for the year 1920 is given as 14.2 bushels per acre. This figure is the average of the yield from 2 plats on fallow, 3 on disked corn ground, 4 on rye used as green manure, 4 on peas used as green manure, and 4 continuously cropped to winter wheat by various cultural treatments. The annual average yield for each of the other crops was similarly obtained. The 15-year averages are a gauge of the cropping possibilities of this region. The average individual using average methods may well hope to equal these yields, and the careful individual using only the best methods may well hope to better them.

TABLE 4.—*Average annual yields from all grain and sorghum plats in the rotation block at the Akron Field Station during the 15-year period from 1909 to 1923, inclusive*

Year	Acre yields of grain (bushels)					Acre yields of total crop (pounds)			
	Winter wheat	Spring wheat	Oats	Barley	Corn	Corn	Kafir	Milo	Sorgo
1909	[1] 14.1	13.8	19.4	19.8	24.9	4,570	10,200	3,940	7,950
1910	14.1	9.2	13.3	12.0	10.9	2,237	2,940	2,864	3,620
1911	4.1	3.7	4.0	6.1	3.2	1,367	3,356	1,713	1,300
1912	33.8	19.7	42.3	30.8	30.9	4,535	4,040	4,116	6,100
1913	7.4	3.9	6.6	6.3	3.9	1,607	2,274	1,540	1,400
1914	25.5	16.6	42.2	37.8	11.3	2,730	2,474	2,582	3,560
1915	21.8	27.3	64.3	55.0	29.2	3,585	2,388	2,152	5,860
1916	13.7	7.1	11.3	11.0	1.1	930	1,514	1,252	550
1917	6.6	13.2	26.2	26.4	15.2	2,798	3,312	2,080	2,350
1918	5.3	1.1	1.4	4.3	12.4	3,076	3,640	4,890	3,200
1919	15.0	6.3	16.9	18.3	4.5	1,620	4,124	2,436	2,150
1920	14.2	18.7	44.2	32.1	35.6	4,356	4,528	4,380	6,270
1921	12.3	2.1	13.1	14.1	6.3	1,223	2,286	1,472	1,560
1922	.6	6.9	15.9	11.7	11.2	2,465	5,520	-------	4,767
1923	2.9	4.6	14.4	18.6	17.9	3,471	2,420	-------	4,775
Average	12.8	10.3	22.4	20.3	14.6	2,705	3,668	2,724	3,694

[1] The yield given for 1909 is of spring wheat seeded after the winter wheat winterkilled.

The average yields also serve to illustrate the variations in the yields of the different crops in different years. Considering all crops, the 15-year period may be roughly divided into five exceptionally good years, when all or nearly all crops produced decidedly better than normal yields; six average years, when all or nearly all crops produced approximately normal yields; and four exceptionally poor years when all or nearly all crops produced decidedly less than normal yields.

One of the outstanding facts shown by Table 4 is the almost certain production of coarse feed by the forage crops. The station results indicate that forage crops are the most dependable crops that can be grown on the average dry farm of this region. Complete failure needs be feared but rarely if dependence is placed each year on a carefully selected variety of crops instead of on one or even two crops. The comparative reliability of the different crops is considered in further detail later in this publication in connection with the individual crops and methods.

RESULTS WITH WINTER WHEAT

Winter wheat stands first among the important small-grain crops for this region. Compared with the other small-grain crops it shows remarkable ability to produce uniformly favorable yields and responds

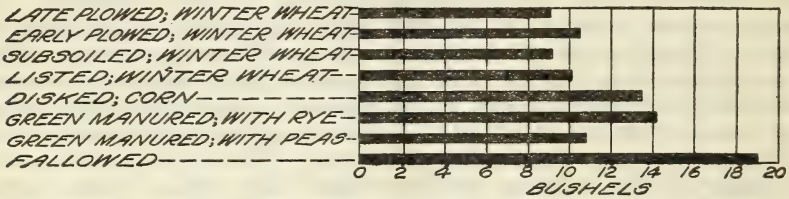

FIG. 5.—Average yields of winter wheat obtained under different tillage methods at the Akron Field Station for the 15 years from 1909 to 1923, inclusive

to good cultural treatment as well as or better than the other small grains.

Winter wheat during the 15-year period produced a normal or nearly normal yield six times, a yield decidedly better than normal three times, and a yield decidedly less than normal six times. The best average yield was 33.8 bushels per acre, in 1912. The lowest average yield was 0.6 bushel in 1922, when it failed completely under most methods. One crop of spring wheat, resulting from reseeding after winterkilling in 1909, is included in these averages.

The yearly production and the 15-year average production of winter wheat under eight different methods of treatment are given in Table 5 and shown graphically in Figure 5.

The yield of winter wheat on fallow is the average of two plats, one in a 4-year rotation and one in a 2-year alternation of winter wheat and fallow. The agreement between the two from year to year is very close, and the 15-year average yields differ by only 0.6 bushel, the difference being in favor of the 4-year rotation.

Fallow as a preparation for winter wheat stands out sharply from the other methods under trial. The 15-year average yield of the two plats on fallow is 19.1 bushels per acre. This is 8.6 bushels per acre more than the highest yielding method under trial in which wheat

follows wheat, and 5.6 bushels more than wheat on disked corn ground. In this bulletin the yields on fallow and the yields on green manure, which is a modified fallow, are given for the area actually in crop. The use of this area is required for two years to produce the one crop. In any one year an area equal to the cropped area produces nothing.

TABLE 5.—*Yields of winter wheat under different cultural methods at the Akron Field Station for the 15 years from 1909 to 1923, inclusive*

Treatment and previous crop	Plats averaged	Yields per acre (bushels)															
		[1]1909	1910	1911	1912	1913	1914	1915	1916	1917	1918	1919	1920	1921	1922	1923	Average
Late fall plowed:																	
Winter wheat	1	14.5	11.4	1.7	25.8	3.3	24.5	22.0	4.2	2.7	2.0	7.6	13.8	3.0	0	0.3	9.1
Early fall plowed:																	
Winter wheat	1	12.9	10.3	6.8	26.7	2.0	24.8	20.8	4.2	5.0	1.5	20.3	13.5	7.0	0	1.5	10.5
Subsoiled:																	
Winter wheat	1	13.3	6.9	3.3	21.2	3.2	24.5	21.0	3.8	5.7	1.2	12.5	15.0	5.8	0	1.2	9.2
Listed:																	
Winter wheat	1	12.2	8.8	4.0	30.0	7.2	21.3	18.2	7.7	3.8	3.0	14.2	11.7	9.0	0	0	10.1
Disked:																	
Corn	3	14.0	17.7	3.1	36.3	11.4	27.7	26.2	15.3	5.9	5.2	13.1	14.9	6.5	1.3	3.2	13.5
Green manured:																	
With rye	4	13.9	15.7	3.7	36.8	8.4	27.2	25.2	19.7	6.4	8.2	14.5	11.7	16.6	1.3	3.1	14.2
With peas	4	13.3	12.7	2.4	33.2	4.2	23.1	13.8	9.7	6.6	2.1	12.8	14.2	10.9	0	2.3	10.8
Total or average	8	13.6	14.2	3.1	35.0	6.3	25.1	19.5	14.7	6.5	5.2	13.7	13.0	13.8	.7	2.7	12.5
Fallowed	2	17.9	18.0	10.6	40.9	12.7	27.0	27.4	24.9	13.2	12.9	26.3	19.3	27.5	.9	7.4	19.1
Average of all 17 plats	------	14.1	14.1	4.1	33.8	7.4	25.5	21.8	13.7	6.6	5.3	15.0	14.2	12.3	.6	2.9	12.8

[1] Winterkilled and reseeded to spring wheat.

The yield on disked corn ground is the average of three plats in as many 4-year rotations. The 15-year average yield of this method is 13.5 bushels per acre. This is 3 bushels per acre more than the best method following wheat and 5.6 bushels less than on fallow. When winter wheat is grown on fallow 2 acres are required to produce 19.1 bushels. When it is grown on corn ground the 2 acres produce 13.5 bushels of wheat and about 14 bushels of corn. In addition to the grain there is also the corn stover. Where the corn can be properly utilized, the disked ground appeals as the most profitable preparation for winter wheat.

The yields following rye as green manure and peas as green manure are each the averages of four plats in separate 4-year rotations. The production on land green manured with peas was but little better than on that producing a crop of wheat each year. The production on land green manured with rye averaged only a fraction of a bushel more than on disked corn ground. Green manuring thus seems to be of no economic value for this section. Green manure, like fallow, requires the use of the land for two years to produce one crop. The relatively poor results from the use of peas may be explained by the fact that they are plowed under at a late date, and the opportunity for storing water in the soil is but little greater than it is where a crop is harvested. Rye is plowed under considerably earlier, and the results following it approach more nearly to those on fallow.

The several methods of preparation by which winter wheat is grown continuously group themselves with no great differences among them but in sharp contrast to fallow and corn ground. The rela-

tively low yields in this group are not due to the continuity of winter wheat but to the immediate preparation as it affects the quantity of water in the soil. Practically the same results would be obtained following any small grain in a rotation. The heaviest yielding of these methods is deep early-fall plowing, which gives a 15-year average of 10.5 bushels per acre. By this method 2 acres will produce 21 bushels of wheat in one year and in an alternate fallowing and cropping system 19.1 bushels. The poorest yielding method under trial is late, shallow, fall plowing, with an average of 9.1 bushels per acre. The evidence indicates that the difference in yield between this plat and the one plowed deep in the early fall is due to the time of plowing and the consequent differences in the seed-bed preparation as affecting the quantity of water in the soil rather than to the differences in the depth of plowing.

The subsoiled plat is plowed at the same time and cultivated and otherwise treated the same as the deep early-plowed plat, except that it is subsoiled at the time of plowing. Subsoiling is done for two years and then omitted for two years. The average yield from this plat is 1.3 bushels per acre less than that from the plat not subsoiled and but 0.1 bushel more than the yield from the plat plowed shallow late in the fall. The yield is 0.9 bushel less than the yield from listing, which is a much cheaper method of soil preparation. These results give no support to the practice of subsoiling for this region, so far as the winter-wheat crop is concerned.

One plat is listed at the time early plowing is done. Before seeding time it is disked level. This takes less time than plowing. The 15-year average yield from this method is 10.1 bushels, as compared to 10.5 bushels from deep early-fall plowing. It appears that listing soon after harvest and subsequently working the ground level, cultivating after each consequential rain, is as good as plowing.

No winter wheat has been grown at this station on disked or uncultivated small-grain stubble, but a thorough investigation of these methods is to be undertaken. Results at some other stations have been remarkably favorable to the omission of plowing under certain conditions.

Experience has shown that it is not possible to estimate accurately the winter-wheat survival at the early date that the spring small grains must be seeded if they are to yield their best. Of the spring-sown small-grain crops that might be used for reseeding, barley or oats are most likely to give a return commensurate with the effort. Barley even seems to show a little more versatility than oats in returning a fair yield under unfavorable circumstances. The spring-sown small grains should not be seeded later than April 10.

Winterkilled winter-wheat ground would serve better for millet, beans, corn, or sorgo, any of which gives ample time to determine the value of the winter-wheat stand. Millet and corn may be seeded May 15 and beans and sorgo as late as June 1.

RESULTS WITH SPRING WHEAT

The 15-year average yield of spring wheat is 10.3 bushels per acre, as compared with an average of 12.8 bushels for winter wheat. Spring wheat produced a higher average yield than winter wheat in only 5 of the 15 years, and in 2 of these 5 years the average yield of

spring wheat was less than 7 bushels per acre. Spring wheat seldom succeeds when winter wheat fails. It is not as reliable as winter wheat over a term of years and does not respond as well to good cultural treatment or to favorable seasons. Spring wheat produced more than the average winter-wheat yield of 12.8 bushels per acre only six times during the 15-year period, and it exceeded its own average yield of 10.3 bushels the same number of times. The highest average yield of spring wheat per acre was 27.3 bushels, in 1915. The lowest yield was in 1918, when most methods failed and the best averaged only 3.9 bushels. Table 6 shows the annual and the 15-year average yields of spring wheat under 13 different methods of soil treatment. The 15-year average yields are shown graphically in Figure 6.

The highest average yield for the 15 years was 13.2 bushels, on fallow. The plat alternately cropped and fallowed averaged 12.5 bushels, and the plat on fallow in the 3-year rotation (No. 5) averaged 14.8 bushels per acre. The next highest yielding preparations were spring-plowed corn ground, 12.6 bushels; fall-plowed corn

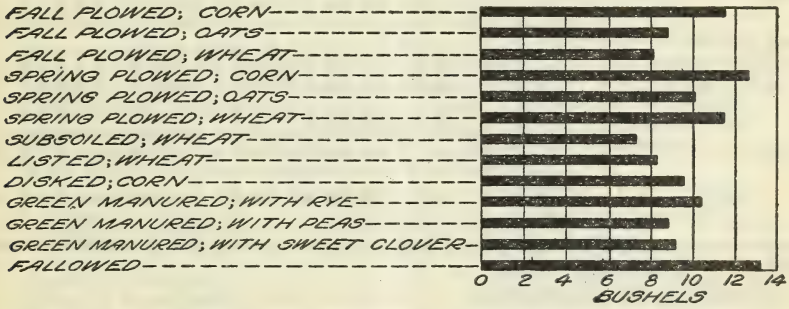

FIG. 6.—Average yields of spring wheat obtained under different tillage methods at the Akron Field Station for the 15 years from 1909 to 1923, inclusive

ground, 11.5 bushels; and spring plowing on land continuously cropped to wheat, 11.5 bushels. The average yield of four plats on disked corn ground was only 9.6 bushels per acre. One of these was in a 3-year rotation and averaged 14 bushels per acre; one was in a 4-year rotation of sweet clover for green manure, oats, corn, and wheat, and averaged 10.5 bushels; one was in a 6-year rotation of bromegrass three years, oats, corn, and wheat, and averaged 6.5 bushels; and one was in a similar sod rotation containing three years of alfalfa and averaged 7.6 bushels. The difference between the yield in the 3-year rotation and the yields in the other rotations was due in part to soil differences due to different locations in the field and in part to the influence of other crops in the rotations. The evidence indicates that the yield of 14 bushels per acre in the 3-year rotation is the one most nearly comparable with the yields incident to other methods already mentioned. If this is true, disked corn ground is equal to fallow as a preparation for spring wheat, is superior to corn ground plowed either in the fall or in the spring, and superior to ground that raised a crop of small grain the preceding year.

TABLE 6.—*Yields of spring wheat under different cultural methods at the Akron Field Station for the 15 years from 1909 to 1923, inclusive*

Treatment and previous crop	Plats averaged	Yields per acre (bushels)															
		1909	1910	1911	1912	1913	1914	1915	1916	1917	1918	1919	1920	1921	1922	1923	Average
Fall plowed:																	
Corn	1	19.2	11.2	3.4	30.3	1.4	14.3	31.2	5.2	16.5	1.5	8.0	16.0	1.7	8.2	3.7	11.5
Oats	3	10.3	5.8	3.7	18.8	.6	13.6	24.1	3.5	10.9	0	8.8	16.2	4.3	5.9	4.8	8.8
Wheat	[1] 2	10.3	6.2	2.1	17.6	.7	11.0	24.0	2.4	13.8	0	6.7	17.2	2.2	3.3	3.5	8.1
Total or average	6	12.1	6.9	3.1	20.3	.8	12.8	25.3	3.4	12.8	.3	7.9	16.5	3.2	5.4	4.2	9.0
Spring plowed:																	
Corn	1	20.8	15.3	1.3	26.5	6.8	18.5	30.0	6.3	15.7	1.3	9.0	22.1	1.7	6.7	6.7	12.6
Oats	1	14.3	6.3	.3	20.3	1.0	21.2	26.5	1.8	16.0	0	3.5	20.4	1.0	9.8	9.2	10.1
Wheat	1	12.2	11.3	2.9	21.3	4.8	22.2	26.3	9.3	19.3	0	7.5	17.4	4.3	6.7	6.8	11.5
Total or average	3	14.9	11.0	1.5	22.7	4.2	20.6	27.6	5.8	17.0	.4	6.7	20.0	2.3	7.7	7.6	11.3
Subsoiled:																	
Wheat	1	11.2	5.5	1.5	16.0	.5	9.8	23.7	1.7	10.3	0	6.0	15.3	1.3	3.3	3.2	7.3
Listed:																	
Wheat	1	9.6	6.8	1.3	17.2	2.1	14.2	23.7	5.5	12.7	0	5.5	15.8	1.2	4.7	3.8	8.3
Disked:																	
Corn	4	15.5	11.4	1.7	19.0	2.8	16.7	27.7	6.3	10.0	0	4.4	19.5	1.6	4.5	3.5	9.6
Green manured:																	
With rye	1	14.7	11.7	3.8	19.2	1.5	15.3	28.7	10.8	13.8	1.3	7.0	16.4	1.8	6.2	3.9	10.4
With peas	1	12.0	12.4	1.8	20.3	1.5	13.3	23.5	3.2	8.8	0	4.3	17.7	1.0	9.3	2.8	8.8
With sweet clover	1	10.1	3.8	1.7	20.5	3.9	11.2	26.2	6.3	20.8	0	5.0	20.3	1.2	6.0	1.5	9.2
Total or average	3	12.3	9.3	2.4	20.0	2.3	13.3	26.1	6.8	14.5	.4	5.4	18.1	1.3	7.2	2.7	9.5
Fallowed	[2] 6	18.4	12.2	8.2	19.1	9.1	21.4	30.8	13.4	13.9	3.9	6.5	20.9	2.1	10.3	8.0	13.2
Average of all 24 plats [3]	------	13.8	9.2	3.7	19.7	3.9	16.6	27.3	7.1	13.2	1.1	6.3	18.7	2.1	6.9	4.6	10.3

[1] One of these was spring plowed in 1909 and listed in 1910 and is included with those methods in those years.
[2] Only 2 plats in 1909, 1910, and 1923.
[3] Only 20 plats in 1909, 1910, and 1923.

Winter rye, peas, and sweet clover are each turned under as green manure and followed by spring wheat in 4-year rotations. The yields of wheat are markedly below those on fallow and little better, if any, than those following a harvested crop of small grain. Yields were heaviest following the rye and lightest following the peas. The differences are traceable directly to differences in the time of plowing the green manures under and consequent differences in the length of the fallow periods and the quantities of water stored in the soil.

The average yields on the listed and the subsoiled plats do not differ materially from the average yield of the fall-plowed plat continuously cropped to wheat with which they are comparable. Following three crops, corn, oats, and spring wheat, the yields on spring plowing averaged better than those on fall plowing. The effect of the time of plowing on yields was considered in detail in Department Bulletin No. 253.[3]

RESULTS WITH OATS

Oats are represented by 31 plats in the rotation and cultivation experiments. The average yield of these plats for the 15 years was 22.4 bushels per acre. The highest yield was in 1915, when all plats

[3] Grace, O. J. The effect of different times of plowing small-grain stubble in eastern Colorado. U. S. Dept. Agr. Bul. 253, 15 p., illus. 1915.

averaged 64.3 bushels per acre; and the lowest was in 1918, when most methods failed entirely and the highest yielding method averaged only 7.7 bushels.

The yields of oats following different crops and cultural treatments are given in Table 7 and shown graphically in Figure 7.

The outstanding method in point of yield is summer fallow, which has a 15-year average of 31.8 bushels per acre. In spite of the fact that it is the highest yielding method, it would not be advisable to raise oats on fallow. In comparison with other crops a relatively greater return was obtained by winter wheat, which averaged 19.1 bushels per acre on fallow, and in comparison with other preparations the yield of oats is not enough greater on fallow to warrant use of fallow for that crop.

Two plats on spring-plowed corn ground averaged 25.4 bushels per acre, and seven plats on disked corn ground averaged 24.2 bushels. On spring plowing following wheat the average yield of oats was 22.7 bushels and on spring plowing following oats it was 22.6 bushels per acre.

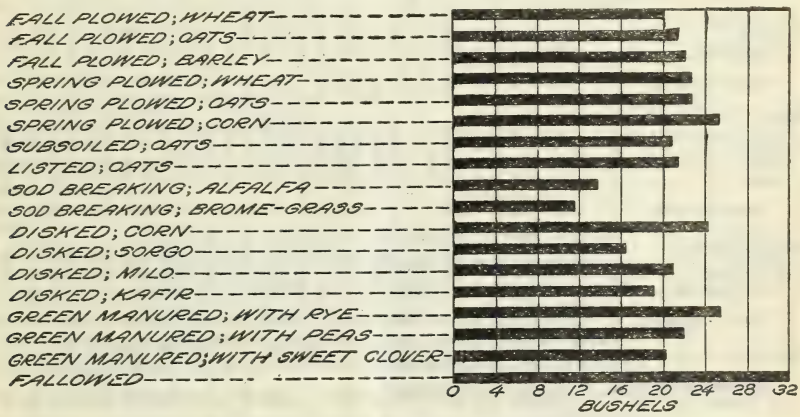

FIG. 7.—Average yields of oats obtained under different tillage methods at the Akron Field Station for the 15 years from 1909 to 1923, inclusive

The yields on fall plowing, listing, and subsoiling were all below the yields on spring plowing following the same crops. There are marked fluctuations or yearly differences in the relations of these methods, but in the average of a series of years the differences are not great enough to be the determining factors in choosing between them. Choice between them is based on economy in the distribution of labor and the conditions under which the work may be done.

The subsoiled plat is directly comparable with the fall-plowed plat on which oats is the preceding crop. It differs from it only by the subsoiling. The difference between the average yields of the two is only a fraction of a bushel and is well within the limits of error.

The yields following disked sorgo, kafir, and milo are distinctly lower than those following corn.

The yields following green manures are lower than those following fallow. The yield following rye as a green manure is about the same as that following corn, but the yields following peas and following sweet clover plowed under for green manures are only equal to those following a harvested crop of grain.

TABLE 7.—*Yields of oats under different cultural methods at the Akron Field Station for the 15 years from 1909 to 1923, inclusive*

Treatment and previous crop	Plats averaged	Yields per acre (bushels)															
		1909	1910	1911	1912	1913	1914	1915	1916	1917	1918	1919	1920	1921	1922	1923	Average
Fall plowed:																	
Wheat	3	19.3	14.1	10.5	47.7	7.6	35.5	55.9	2.6	25.8	0	24.4	21.2	14.2	10.1	8.5	19.8
Oats	1	14.1	8.0	15.9	46.9	.6	36.9	57.2	7.2	29.7	0	32.8	34.9	14.7	12.2	9.7	21.4
Barley	1	20.8	10.2	15.9	37.2	.6	39.1	57.2	7.8	28.8	0	27.8	36.3	21.6	12.5	14.2	22.0
Total or average	5	18.6	12.1	12.7	45.5	4.8	36.5	56.4	4.6	27.2	0	26.7	27.0	15.8	11.0	9.9	20.6
Spring plowed:																	
Wheat	1	18.3	14.8	1.7	46.9	16.6	47.5	56.9	2.2	39.1	0	11.6	45.8	6.6	18.8	14.1	22.7
Oats	1	21.0	10.9	4.4	41.9	6.6	39.4	56.9	9.1	38.1	0	24.7	39.0	10.0	19.7	16.7	22.6
Corn	2	21.6	20.8	5.3	49.6	5.0	49.4	71.4	12.7	32.1	0	17.4	47.0	11.4	16.6	20.7	25.4
Total or average	4	20.6	16.8	4.2	47.0	8.3	46.4	64.2	9.2	35.3	0	17.8	44.7	9.9	17.9	18.1	24.0
Subsoiled:																	
Oats	1	16.1	11.3	8.4	35.3	0	30.3	57.5	4.1	28.4	0	30.0	50.9	19.1	6.6	12.8	20.7
Listed:																	
Oats	1	15.6	11.1	5.3	54.7	3.6	40.9	50.0	13.1	31.3	1.3	25.3	35.9	10.3	5.9	13.8	21.2
Sod breaking:																	
Alfalfa	1	8.8	2.7	0	29.4	1.9	30.6	49.1	1.6	10.0	0	10.9	42.8	10.6	1.6	6.1	13.7
Bromegrass	1	20.2	2.2	0	27.5	1.6	35.0	34.7	0	3.4	0	1.9	30.7	3.8	3.1	9.1	11.5
Total or average	2	14.5	2.5	0	28.5	1.8	32.8	41.9	.8	6.7	0	6.4	36.8	7.2	2.4	7.6	12.7
Disked:																	
Corn	7	20.9	18.2	.4	38.5	7.3	48.5	68.5	18.0	25.7	1.9	11.9	55.7	13.2	18.7	15.1	24.2
Sorgo	1	16.1	5.0	0	25.0	1.9	37.8	57.8	1.6	17.8	0	3.1	41.3	11.3	12.8	15.2	16.4
Milo	2	15.7	12.2	0	41.9	7.2	40.7	69.2	10.2	22.1	0	2.7	44.9	7.8	14.9	(1)	20.7
Kafir	2	14.6	6.7	0	40.3	5.5	40.5	64.0	14.2	17.1	0	5.4	45.7	5.8	13.1	12.5	19.0
Total or average	12	18.6	14.2	.2	38.2	6.5	45.0	67.0	14.7	23.0	1.1	8.5	51.0	10.9	16.6	14.7	22.0
Green manured:																	
With rye	1	21.0	20.0	2.7	38.4	5.0	44.4	76.6	15.6	37.2	5.5	17.5	43.9	17.8	20.9	15.1	25.4
With peas	1	22.0	11.9	0	38.4	1.3	38.1	69.1	8.1	20.0	0	11.9	56.3	17.8	18.1	11.9	21.7
With sweet clover	1	13.0	5.2	3.9	45.8	5.0	41.6	76.6	5.0	21.3	0	23.8	35.8	4.1	14.7	7.6	20.2
Total or average	3	18.7	12.4	2.2	40.9	3.8	41.4	74.1	9.6	26.2	1.8	17.7	45.3	13.2	17.9	11.5	22.4
Fallowed	3	28.9	17.1	7.1	56.4	16.5	45.9	79.2	22.5	35.4	7.7	31.8	49.1	24.3	31.5	23.9	31.8
Average of all 31 plats	------	19.4	13.3	4.0	42.3	6.6	42.2	64.3	11.3	26.2	1.4	16.9	44.2	13.1	15.9	14.4	22.4

[1] These two plats were on disked sorgo after 1922.

The lowest yields were obtained following the breaking of sod in the alfalfa and bromegrass rotations. The 15-year average yield on bromegrass sod was only 11.5 bushels per acre and on alfalfa sod 13.7 bushels. These reduced yields are largely due to the dry condition in which the sod crop leaves the soil. These plats often are the first in the field to suffer from drought.

RESULTS WITH BARLEY

Barley is represented by nine plats in the crop-rotation and cultivation experiments. The annual and average yields of the seven methods under trial with this crop for the 15 years from 1909 to 1923, inclusive, are given in Table 8 and shown graphically in Figure 8.

The average yield of the nine plats for the 15 years was 20.3 bushels per acre. The highest average yield was 55 bushels, in 1915; and the lowest was 4.3 bushels, in 1918.

TABLE 8.—*Yields of barley under different cultural methods at the Akron Field Station for the 15 years from 1909 to 1923, inclusive*

Treatment and previous crop	Plats averaged	Yields per acre (bushels)															
		1909	1910	1911	1912	1913	1914	1915	1916	1917	1918	1919	1920	1921	1922	1923	Average
Fall plowed:																	
Barley	1	16.8	10.5	16.3	27.9	3.1	36.7	47.9	5.0	26.9	1.0	23.7	23.4	10.8	7.7	13.0	18.0
Spring plowed:																	
Barley	1	19.7	13.1	8.7	28.8	4.6	32.1	43.1	4.4	27.3	2.1	18.8	19.6	7.5	9.8	16.9	17.1
Oats	1	22.2	10.2	2.3	35.2	7.9	40.2	50.0	6.5	32.9	3.1	18.3	29.3	7.5	15.8	20.0	20.1
Total or average	2	21.0	11.7	5.5	32.0	6.3	36.2	46.6	5.5	30.1	2.6	18.6	24.5	7.5	12.8	18.5	18.6
Subsoiled:																	
Barley	1	19.8	6.9	5.2	22.5	1.5	27.9	52.3	4.2	13.5	0	15.8	31.9	10.6	6.9	13.8	15.5
Listed:																	
Barley	1	19.2	12.6	4.6	36.0	4.4	30.8	46.0	9.4	29.2	4.4	20.4	30.1	11.7	5.0	15.1	18.6
Disked:																	
Corn	3	18.7	12.9	1.7	28.9	6.4	42.0	60.5	16.4	23.1	5.5	11.4	37.5	14.8	11.8	19.7	20.8
Fallowed	1	24.6	16.0	12.6	40.2	16.3	46.3	73.7	20.4	38.3	11.3	33.5	41.9	34.2	24.6	29.8	30.9
Average of all 9 plats		19.8	12.0	6.1	30.8	6.3	37.8	55.0	11.0	26.4	4.3	18.3	32.1	14.1	11.7	18.6	20.3

The highest yielding method was fallow, which gave an average of 30.9 bushels per acre for the 15 years. This average was made up of yields ranging from 73.7 bushels in 1915 to 11.3 bushels in 1918. The next highest average yield was 20.8 bushels on three plats of disked corn ground.

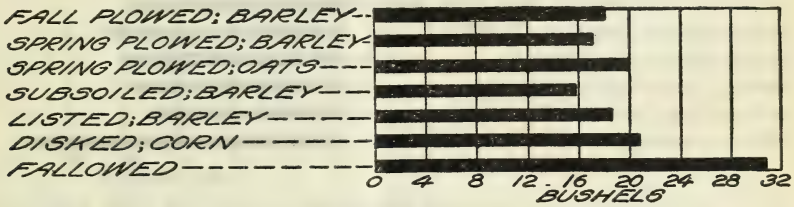

FIG. 8.—Average yields of barley obtained under different tillage methods at the Akron Field Station for the 15 years from 1909 to 1923, inclusive

One plat on spring plowing following oats in a 3-year rotation of corn, oats, and barley averaged 20.1 bushels per acre.

The other four plats of barley raised that crop continuously. One was spring plowed, one fall plowed, one subsoiled, and one listed. The lowest yield was on the subsoiled plat, which averaged only 15.5 bushels per acre. The average yields of the other three were 18 bushels on the one plowed in the fall, 17.1 bushels on the one plowed in the spring, and 18.6 bushels on the one listed in the fall.

RESULTS WITH CORN

Corn occupied 27 plats in the experiments with rotation and cultural methods. The annual and average yields of the 13 preparations represented in the 27 plats are given in Table 9 and shown graphically in Figure 9.

The 15-year average yield of all plats was 14.6 bushels per acre. This is 1,022 pounds of ear corn, or 818 pounds of shelled corn. The average yield of corn in pounds of grain per acre is exceeded only

by that of barley. The general experience at Akron indicates that corn produces better on sandy land than on the heavier soil at the station.

The highest average yield was 35.6 bushels, in 1920. There was no complete failure, but many methods failed to produce grain in 1911, 1913, and 1916, years of drought.

The highest average yield under any method was 23.1 bushels per acre, on summer fallow. The higher average from this preparation is due not so much to increased yields in the better years as to increases in the years of medium yields and in the poorer years when other methods were nearly or quite overcome by drought. No complete failure has been recorded on summer-fallowed land, the lowest yield on this preparation being 8.4 bushels, in 1919.

The next three highest average yields were produced by continuous cropping to corn. Under this system the 15-year average yield was 17.9 bushels on fall plowing, 17.6 bushels on spring plowing, and 16.2 bushels on subsoiling. These results show the feasibility of raising corn continuously on the same land if this is required by the type or

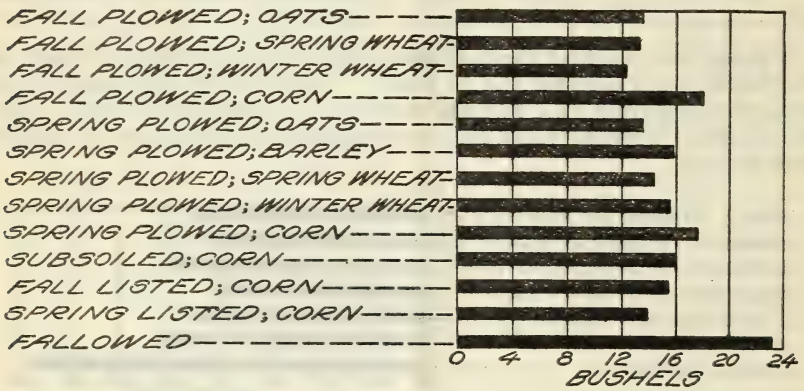

FIG. 9.—Average yields of corn obtained under different tillage methods at the Akron Field Station for the 15 years from 1909 to 1923, inclusive

system of farming practiced, but that if small grain is to be grown also labor will be conserved and greater relative returns realized if the corn and small grains are rotated.

Two other plats were cropped continuously to corn. One was listed in the fall and planted with a lister, splitting the ridges. The other was planted with a lister without previous cultivation. The one listed in the fall averaged 15.6 bushels, and that listed in the spring averaged 13.9 bushels. At the station corn does not start as quickly and vigorously when listed as when surface-planted, and difficulty is sometimes experienced in getting a stand. This happens especially when heavy rains flood the furrows. When this occurs the surface becomes crusted on drying and the seed may rot or the seedlings be unable to emerge, or, if further advanced, the seedlings may be covered by soil washed into the furrows. On the other hand, listed corn frequently withstands drought somewhat longer or better than that surface-planted. General experience in this region is that listing is of relatively greater value on the lighter and warmer soils than on the heavier land.

TABLE 9.—*Yields of corn under different cultural methods at the Akron Field Station for the 15 years from 1909 to 1923, inclusive*

Treatment and previous crop	Plats averaged	Yields per acre (bushels)															
		1909	1910	1911	1912	1913	1914	1915	1916	1917	1918	1919	1920	1921	1922	1923	Average
Fall plowed:																	
Oats	6	26.8	8.0	7.0	30.1	1.0	11.0	31.9	0	12.7	7.9	6.4	35.1	4.8	8.8	13.0	13.6
Spring wheat	3	22.2	6.1	5.8	32.5	0	7.0	31.1	0	13.1	8.9	4.5	35.1	5.5	9.8	17.3	13.3
Winter wheat	3	22.7	8.7	1.8	27.4	0	8.2	29.6	0	13.7	8.8	3.8	31.7	6.6	8.2	16.1	12.5
Corn	1	27.3	18.3	0	46.9	9.9	17.3	29.2	4.8	21.9	12.6	5.0	36.9	3.1	15.3	19.9	17.9
Total or average	13	24.8	8.5	5.0	31.3	1.2	9.9	31.0	.4	13.7	8.7	5.3	34.4	5.2	9.4	15.2	13.6
Spring plowed:																	
Oats	4	25.9	7.4	.5	28.0	2.6	11.9	33.5	0	13.2	10.3	.9	38.2	3.7	8.0	19.5	13.6
Barley	1	21.7	16.6	0	34.9	9.9	13.9	30.3	0	16.7	13.4	5.9	36.9	9.5	11.7	15.1	15.8
Spring wheat	2	21.1	14.6	.4	36.7	0	11.3	30.9	0	15.0	11.5	1.3	35.4	6.4	7.7	24.5	14.5
Winter wheat	2	22.2	10.7	.4	29.3	9.2	12.2	28.6	0	22.1	10.8	3.2	41.3	8.5	8.9	25.3	15.5
Corn	1	30.0	21.6	1.3	33.9	13.6	15.9	21.9	7.1	25.1	13.1	4.1	35.5	7.0	14.7	19.1	17.6
Total or average	10	24.2	11.8	.5	31.3	5.2	12.4	30.5	.7	16.9	11.2	2.3	37.8	6.1	9.2	21.2	14.8
Subsoiled:																	
Corn	1	32.9	12.7	0	37.1	4.3	13.9	22.3	3.2	20.6	18.5	5.8	35.9	3.5	15.0	17.9	16.2
Fall listed:																	
Corn	1	22.4	15.1	2.6	27.2	10.7	11.6	14.4	1.7	6.9	36.4	9.8	31.9	7.7	24.2	11.5	15.6
Spring listed:																	
Corn	1	29.7	15.1	0	16.7	7.2	7.3	24.8	3.1	9.5	23.0	6.1	27.3	11.0	20.8	7.2	13.9
Fallowed	1	25.0	21.4	12.9	33.6	13.8	18.6	19.6	9.7	27.4	32.6	8.4	40.1	19.0	29.6	35.3	23.1
Average of all 27 plats		24.9	10.9	3.2	30.9	3.9	11.3	29.2	1.1	15.2	12.4	4.5	35.6	6.3	11.2	17.9	14.6

The average yields of corn on both fall plowing and spring plowing following wheat and oats ranged from 12.5 to 15.5 bushels per acre. The evidence is extensive, but it does not warrant a conclusion that any one of the small grains provides a preparation for corn that is either better or poorer than that provided by any other one of them.

Comparisons between spring plowing and fall plowing, each following four crops, are offered. Distinct differences are shown between them in different seasons, in favor sometimes of one and sometimes the other, but in the averages for the 15 years the differences are small. The 15-year average yield on 13 fall-plowed plats was 13.6 bushels, and on 10 fairly comparable spring-plowed plats it was 14.8 bushels.

The average yield of corn stover in addition to the grain was 1,685 pounds per acre. This with the 1,022 pounds of ears makes a total production of 2,707 pounds of feed per acre. Corn never failed to produce stover, but it averaged only 782 pounds per acre in 1921 and 843 pounds in 1916. The highest average annual yield was 2,827 pounds, in 1909. The highest 15-year average yield, 2,024 pounds, was on fallow. The yields of the different preparations ranged from that down to 1,513 pounds on spring listing.

RESULTS WITH OTHER CROPS

Both kafir and milo were included in two rotations and three continuously cropped plats. Milo was discontinued after 1921. The range of methods to which these crops have been subjected should have developed whatever possibilities they may have for this section, the writer believes.

Kafir and milo are grown primarily as grain crops in the region to which they are adapted. At the Akron station they matured a seed crop only occasionally, although the earliest varieties were used. It is more difficult to obtain a seasonable stand of them than it is other crops. This is undoubtedly due to low temperatures of the soil.

Planting in lister furrows was much inferior to surface planting on either fall or spring plowing. This was due to a poorer stand and a slower start from listing. Between fall plowing and spring plowing there was little or no difference on the average.

Kafir was the more valuable of the two crops. It matured as much grain as milo and gave an average yield of 1¾ tons of dry forage per acre, whereas the average yield of milo was but little more than 1¼ tons. Kafir is more leafy than milo and makes forage of better quality. Kafir seems to have possibilities of sharing with sorgo the rôle of being the important forage plant for this region, but the preference as shown by general practice is for the sorgo, a crop that matures.

Sudan grass does well at Akron but has not been used in any of the rotations. It does not yield as heavily as sorgo, but the forage is of a different type. Its place depends very much upon the favor with which the individual grower views the haylike forage it makes. As an annual fall-pasture crop it is certain, produces well, and is relished by stock. Sudan grass for pasture should be seeded after corn planting is finished, preferably in narrow rows 30 inches apart, It should be cultivated once to give the plants a start over the weeds. It should furnish pasture from one month after seeding until frost. Sudan grass can be highly recommended as a fall pasture for hogs.

Alfalfa and bromegrass each appear in 6-year rotations. The sod crops occupy the land for three years, including the year of seeding, and are followed by oats, corn, and wheat. These rotations furnish data on the possibility of obtaining a stand and establishing a sod each year and are long enough to indicate the relative values of the two crops and their effects on succeeding crops. From the results it seems that the sod crops are not adapted to short or definite-term rotations. More or less difficulty has been experienced in obtaining stands, particularly in dry seasons. After the sod was broken up, the yields of the crops that immediately followed were below those on land that had not been in sod.

Alfalfa and bromegrass are not satisfactorily productive as hay crops, but alfalfa is the more valuable of the two and is to be recommended as the best sod crop at present available. It does best on land that is subirrigated or that receives run-off from adjoining fields. Many farms have favored locations where alfalfa can be grown successfully. An afalfa pasture is especially desirable in hog production.

Perhaps the most generally followed and most successful practice in seeding dry-land alfalfa is to plow the ground in the spring about the time active weed growth starts and then treat it as bare fallow until about the 1st of August. By that time a large part of the weed seeds will have germinated, been destroyed, and sufficient water will have been stored in the soil to encourage rapid growth of the alfalfa. Advantage is taken of favorable conditions to seed any time after about August 1. If the alfalfa is out of the ground by the middle or last of August there is little danger of its winterkilling, and it is then in condition to make good growth the following year.

Sweet clover is a legume little used and but partially appreciated which offers considerable promise for both hay and pasture. It has been grown and studied as a green-manure crop in two rotations. These have given continuous data on the possibilities of obtaining a stand when seeded with a nurse crop. In one rotation the sweet clover is sown with oats and in the other it is sown with wheat. In both it is sown on disked corn ground. In June of the second year the crop is plowed under when it is in bloom and has attained nearly its maximum growth. The wheat is seeded at the rate of 4 pecks, the oats at 5 pecks, and the sweet clover at 10 pounds, per acre. A good stand is generally obtained, but the sweet clover survives the harvest of the grain in only about 4 years out of 10. When the season is particularly dry before and immediately following harvest the seedling plants are likely to die, the nurse crop exhausting the soil of all available water. Green manuring is considered under a separate heading.

Sweet clover may be spring-seeded on well-prepared spring-plowed land with a fair degree of success. Scarified seed should be used. Sweet clover will hold its own and survive with a much heavier weed growth than alfalfa. Unless soil blowing is a factor a nurse crop is not desirable, the sweet clover finding enough competition from the weeds which will naturally spring into growth. If a nurse crop is used it should be seeded very lightly. Instead of the 5 pecks per acre seeded in the rotation plats, oats should be seeded at the rate of not more than 2 pecks. Sweet clover may be seeded any time in April or May. Barley would seem to be the best nurse crop to use, as it is the earliest of the spring-sown small grains.

It appears that early spring seeding of sweet clover in small-grain stubble may be a successful method of getting a stand. Nothing is risked except the seed. Scarified seed should be sown from April 1 to 10. If unscarified seed is used, the seeding in small-grain stubble should be done in the late fall.

Winter rye is a crop of considerable importance to this region. It is particularly valuable on the lighter soils, where, on account of its greater hardiness, it is less liable than winter wheat to destruction or damage by soil blowing. It is especially valuable for early-spring pasture. It may be utilized solely for pasture; or, after a limited period of pasturing, it may be left to produce a grain crop. Under drought or other unfavorable conditions more reliance is to be placed in it than in any of the other grain crops for producing a good crop of straw, but hot weather and a lack of water at blossoming time may interfere with the production of grain. In the better years rye can not compete with winter wheat on the heavier soils to which wheat is adapted, but in the years when the yield of wheat is low it may be equaled or even exceeded by winter rye. Winter rye is a more certain grain-producing crop for the sandy land than winter wheat. A farmer growing winter wheat should be slow to grow rye for seed production. Rye is extremely hardy and it may come up as volunteer in later seedings of wheat, thus subjecting the latter crop to dockage.

Experiments with potatoes indicate that from 60 to 100 bushels per acre may be expected as an average. Producing certified seed potatoes on the dry lands has come to be profitable in certain sections.

The highest production of potatoes has been found to come in a rotation following some crop grown in rows, such as corn or beans. Potato land as preparation for other crops should be equal to corn ground or slightly superior. Potatoes may be planted the last of March or the first of April for an early crop, in which case they are likely to mature and be subject to second growth under favorable rains of August if not harvested. Potatoes may be seeded as late as May 1.

FALLOW

The object of the fallow is to accumulate and conserve water in the soil during a season, in order that a crop may start with a reserve supply. The two most important considerations are to have the surface coarse and open, to facilitate the penetration of water and prevent run-off and to keep the surface free from vegetation. The most important is to prevent the growth of vegetation. Fallowing as a preparation for succeeding crops loses its effectiveness in direct proportion as these two requirements are not met. To prevent weed growth the land must be cultivated, and this cultivation must be of such a character that it does not pulverize the soil too much. A surface that is too fine probably will puddle in hard rains and the water run off, and the soil will bake and be subject to blowing.

Experiments in methods of fallowing have shown that the least cultivation that will keep the ground bare during the active growing season is not only the cheapest but the most effective. Just as spring plowing for immediate cropping is as good as fall plowing, so nothing is gained by beginning the cultivation for fallow in the fall. The first treatment may be either disking or plowing. Disking in the spring holds the weeds in check, so the plowing can be somewhat later than otherwise would be most effective. Delaying the plowing reduces the number of cultivations that must be given after it is done. Even if it has been disked, the ground should be plowed not later than about June 1.

The implement most commonly used for cultivating the fallow has been the disk harrow. With the disk, the repeated diskings that are necessary make too fine and smooth a surface and thus encourage blowing and run-off. Shovel cultivators are much to be preferred to the disk harrow.

A lister may be used instead of a plow in fallowing. The cultivation to prevent weed growth during the summer levels the furrows and prepares the ground for seeding. This method has not been under trial at the Akron station, but at other stations it has given results at least as good as plowing. On a farm having listers and lister cultivators this method of fallow may fit into the farming system better than any other.

In considering the several crops it has been shown that the outstanding value of fallow in this section is as a preparation for winter wheat. However, in case of prolonged drought in late summer, fallow will not insure a stand of winter wheat unless there is sufficient rainfall at or near seeding time to connect the surface moisture with the stored moisture below.

GREEN MANURES

The green-manured plats may be considered as modified fallows. The cost of the seed and seeding of the crop plowed under makes them more expensive than bare fallows, and in addition they require the sacrifice of a crop already produced. For a green manure to be relatively profitable the crop or crops following it must yield considerably more than those following bare fallow, but they have actually yielded less. The yields following them decrease in comparison to those following fallow as the date of plowing becomes later. The same effect is noted in experiments on the time of plowing for fallow. The beneficial effects of the fallow decrease as the date of plowing is delayed and weeds are permitted to grow. The same result follows the growth of weeds after plowing and emphasizes the necessity of keeping fallow land free from weed growth.

There is little to choose between allowing weeds to grow until July 17 and plowing them under, and allowing peas to grow until the same date. The only observed difference between them is that the latter is a legume and capable of adding nitrogen to the soil, whereas the former is a heterogenous nonleguminous crop. This difference, however, can not manifest itself in the results because of the overpowering control of the moisture factor. Both crops more or less completely exhaust the available water from the soil before they are plowed under. The greater moisture supply in fallow land, it is thought, accounts almost entirely for the greater yields.

The 15-year average yield of winter wheat following fallow plowed on the average date of June 3 was 19.1 bushels per acre; following rye plowed under for green manure on the average date of June 12 the average yield was 14.2 bushels per acre; and following peas plowed under for green manure on the average date of July 17 the average yield was only 10.8 bushels per acre. The latter was practically the same as the yield on land from which a crop of wheat was harvested. With such late plowing the water in the soil is exhausted, and the season of heaviest rainfall being past there is little opportunity to store more.

The difference between fallow, rye for green manure, and peas for green manure, in their effect upon the immediately succeeding crop, seems to be primarily one of the length of the fallow season and the consequent differences in the quantity of water stored in the soil at seeding time. The first crop restores the land to uniformity in this respect. The second and third crops following the green manures do not show any increases over crops in corresponding positions following fallow. Neither do successive repetitions of the treatments as the rotations are repeated show any cumulative advantage from the green manures. The evidence inclines to favor the bare fallow.

Sweet clover is used in the experiments as a green manure, and the same general effect is noted as with rye and peas. Any difference in fertility that might result from the green manure can not manifest itself in the subsequent crop yields because of limited moisture.

CROPS ON PRAIRIE SOD

Statistics published by the Colorado State Board of Immigration [4] show that less than one-third of the land of northeastern Colorado is now under cultivation. This indicates that there is still considerable acreage under sod that is suitable for crop production.

The crop most commonly grown on newly broken prairie sod in this region is winter wheat. There is probably no better preparation for this crop than that afforded by sod. When properly handled, sod is as good as or even better than fallow, and there is probably no better crop than winter wheat to raise on the sod for the first year or two. For the best result, sod should be broken between the middle of May and the middle of June. Sod broken earlier than the middle of May is subject to seeding by Russian thistles carried by the heavy winds of early spring. Breaking later than June 15 restricts the prospective wheat yield by reducing the quantity of water stored in the soil after breaking stops the use of water by the grass.

It is neither common practice nor good policy to break sod deeper than necessary to make the plow work well. The usual plowing depth in this short-grass sod is about 3 inches. A specially designed sod plow is almost a necessity. The sod slice should be turned completely over and laid flat. If the plow does not turn the furrow slice over so that it lies flat, it is advisable to follow the plow with a heavy roller or a heavily weighted disk with the disks set straight. Sod lying flat holds moisture better and rots better than when on edge.

It should not be necessary to cultivate the sod during the summer, but enough cultivation should be done before seeding so that the drill can cover the seed. Generally a good double disking and harrowing is all that is necessary. The best seed bed is obtained when the surface of the sod is fined without turning it over or loosening and roughening it by tearing it out of place.

The foregoing statement applies to the treatment of sod as a fallow in preparation for winter wheat. It is often necessary to use sod land for a crop the first year. Sorgo and proso (hog millet) are well adapted to this purpose, and these, in wet seasons, will produce heavy crops of feed while in average seasons they will produce satisfactory crops. Such production is at least partly at the expense of the following crop, however.

Pinto or Mexican beans have also been used successfully as a first-season crop on breaking. Winter wheat following beans is much more successful than when following sorgo. No attempt is made to intertill such crops as beans and sorgo when planted on prairie sod.

SOIL BLOWING

Soil blowing appears to become a more serious factor, especially with winter wheat, as more sod land is broken and as the land already under cultivation becomes more disintegrated and broken down from its original fresh-plowed condition. If the winter wheat does not emerge in the fall, or if it emerges too late to make any consid-

[4] Colorado State Board of Immigration. Yearbook, 1923, 170 p., illus. 1923.

erable growth, and if the winter and early spring are dry, there is considerable danger from soil blowing, even on the hard land.

The greatest danger of soil blowing is during February, March, and April. Hard winds after the 1st of May usually cause only very local movements of soil, because the spring vegetation is then large enough to prevent movement over any considerable area. It is during these months that the heaviest winds of the year are likely to occur. It is also during these months that the soil, fined and leveled through alternate freezings and thawings of the winter, is most subject to blowing. Normally, soil blowing is not a serious factor on the hard land, but it may become very serious in some years when the early spring precipitation is light and the winds are especially hard and shifting. Blowing is always a hazard on the soft or sandy lands, and cropping practices must be designed with it in mind.

The best protection against soil blowing is a vegetable covering. Where the blowing hazard is great a certain percentage of the land is best left in permanent pasture.

As winter wheat is the crop most subject to damage from soil blowing, on soft or sandy lands it should be seeded on wheat or corn stubble. The corn stubble offers the more favorable chance of producing a wheat crop, but it affords less protection from soil blowing than wheat stubble. The corn-stubble protection is better when the stover is left standing. The forage can be pastured by cattle or horses during the winter months without damage to the wheat. The standing cornstalks may be flattened with a stalk cutter or by dragging a log or pole over the field, a horse hitched to each end, the best time being when the ground is frozen. If the ground is frozen, the stalks will be snapped off even with the ground and will not later interfere with harvesting. The standing cornstalks will rather effectively catch a maximum of the drifting snow through the winter. Where winter wheat is sown in small-grain stubble, the aim should be to leave as much of the stubble intact as possible.

On open fields where the wheat crop has not become firmly established much can be done to prevent blowing by cultivating and roughening the surface soil. Soil blowing starts from a single spot or a number of such spots. The spread from the starting point is fan shaped in the direction of the wind. The movement from this single small area, unless stopped by cultivation, spreads as long as the heavy wind blows and may cross into adjoining fields. One field blowing badly may be the means of setting into motion the soil of adjacent fields in the path of the wind. The soil which has blown during one windstorm remains in ideal condition to blow when the next heavy wind occurs unless cultivated meantime. Obviously, the thing to do is to break up the tendency to blow before any considerable movement has taken place. A corn cultivator with all shovels but one on each beam removed is very effective for cultivating blowing areas, and it causes a minimum damage to the wheat crop. By promptly cultivating the point or points at which the blowing starts the blowing may be kept effectively under control. If the movement has attained considerable headway, always begin at the source on the side with the wind and cultivate back and forth at right angles to the direction of the wind, cultivating until the entire blowing area has been covered. The most important

thing is to cultivate promptly before any considerable areas are involved. Although the cultivation of a winter-wheat field gives the impression at the time that great damage is being done, observation at harvest will not confirm the earlier fears. The damage from effective cultivation can not be as great as will result from soil blowing which is allowed to continue through the spring months. If the cultivation or repeated cultivations fail to control the blowing, then listing out the field is the last resort. The closeness of the lister furrows will depend upon the seriousness of the condition to be met.

SUMMARY AND RECOMMENDATIONS

The Akron Field Station, located in northeastern Colorado on clay-loam soil at an altitude of approximately 4,600 feet, is typical of a large area of the west-central Great Plains.

The annual precipitation averages 17.95 inches, and during the 16-year period from 1908 to 1923, inclusive, ranged from 13.44 to 25 inches. The average is so near the critical point for successful crop production that yields are governed very closely by the quantity and the distribution of the precipitation preceding and during the cropping season.

Winter wheat is not only one of the best adapted and generally most profitable grain crops for this region but is also the most responsive to cultural methods. The yield of winter wheat on fallow has averaged 19.1 bushels, on disked corn ground 13.5 bushels, and on land continuously cropped to wheat and deep fall plowed 10.5 bushels per acre. Spring wheat shows no such response to fallow, but following either corn or small grain it averages practically the same as winter wheat. As neither the seeding nor the harvest of the two conflict, the use of both makes possible the utilization of equipment in the growth of a large acreage.

Barley is the most productive of the feed grains and is also quite responsive to cultural treatment. Oats do not produce grain as heavily as barley but have a special feed value and also have possibilities as a hay crop.

Corn and the sorghums as forage and silage crops are very productive and reasonably sure. They have no total failures. The yield of ear corn averages only slightly less than that of barley.

So far, yields have not been increased by subsoiling or deep tilling.

The relative value of fall plowing as compared with spring plowing of small-grain stubble depends upon the season, but over a series of years there was an advantage in favor of the spring plowing.

The yield of the first crop following green manure is less in comparison with one following fallow. The same lessening of yield results from delay in plowing the fallow. The growth of the green-manure crop or of weeds on fallow land uses the water in the soil and so defeats the object of the fallow. The green manures have not increased the yields of the second or third crops following them, nor were any cumulative benefits shown as the rotations were repeated.

Sod crops have not themselves been productive in 6-year rotations, and they have served to decrease rather than increase the yields of the crops immediately following.

The small grains, either fall or spring sown, do not follow sorgo as well as they do corn. Where possible, sorgo land should be seeded to some row crop that is planted late in the spring.

The average annual yields of the several crops, their response to cultural methods, the effect of a crop upon the yield of the one that follows it, and the possibility of avoiding failure by growing crops of different habit or season indicate that the most stable type of agriculture for this region will be a diversified one with livestock as the main source of dependence and with less emphasis on the cash grain crops. Corn for silage and grain feed and the sorghums for hay and forage offer a reliable and safe foundation for the livestock industry. Corn may be grown continuously with advantage to its yield, but the usual relative values are such that its rotation with small grain, either winter wheat or barley, will be more profitable. Such a rotation distributes the labor, minimizes the probability of failure, and grows the small-grain crop on a favorable preparation and at a low cost per acre. More extensive grain production would be based upon winter wheat and a liberal use of the fallow.

ORGANIZATION OF THE UNITED STATES DEPARTMENT OF AGRICULTURE

December 15, 1924

Secretary of Agriculture	HOWARD M. GORE.
Assistant Secretary	
Director of Scientific Work	E. D. BALL.
Director of Regulatory Work	WALTER G. CAMPBELL.
Director of Extension Work	C. W. WARBURTON.
Solicitor	R. W. WILLIAMS.
Weather Bureau	CHARLES F. MARVIN, *Chief.*
Bureau of Agricultural Economics	HENRY C. TAYLOR, *Chief.*
Bureau of Animal Industry	JOHN R. MOHLER, *Chief.*
Bureau of Plant Industry	WILLIAM A. TAYLOR, *Chief.*
Forest Service	W. B. GREELEY, *Chief.*
Bureau of Chemistry	C. A. BROWNE, *Chief.*
Bureau of Soils	MILTON WHITNEY, *Chief.*
Bureau of Entomology	L. O. HOWARD, *Chief.*
Bureau of Biological Survey	E. W. NELSON, *Chief.*
Bureau of Public Roads	THOMAS H. MACDONALD, *Chief.*
Bureau of Home Economics	LOUISE STANLEY, *Chief.*
Bureau of Dairying	C. W. LARSON, *Chief.*
Fixed Nitrogen Research Laboratory	F. G. COTTRELL, *Director.*
Office of Experiment Stations	E. W. ALLEN, *Chief.*
Office of Cooperative Extension Work	C. B. SMITH, *Chief.*
Office of Publications	L. J. HAYNES, *Director.*
Library	CLARIBEL R. BARNETT, *Librarian.*
Federal Horticultural Board	C. L. MARLATT, *Chairman.*
Insecticide and Fungicide Board	J. K. HAYWOOD, *Chairman.*
Packers and Stockyards Administration *Grain Futures Administration*	CHESTER MORRILL, *Assistant to the Secretary.*

This bulletin is a contribution from—

Bureau of Plant Industry	WILLIAM A. TAYLOR, *Chief.*
Office of Dry-Land Agriculture Investigations.	E. C. CHILCOTT, *Senior Agriculturist in Charge.*

28

ADDITIONAL COPIES
OF THIS PUBLICATION MAY BE PROCURED FROM
THE SUPERINTENDENT OF DOCUMENTS
GOVERNMENT PRINTING OFFICE
WASHINGTON, D. C.
AT
5 CENTS PER COPY

▽